

ORGANIC MATTER FRACTIONS FROM PACIFIC NORTHWEST SOILS: DEPTH AND TILLAGE EFFECTS

Stephan L. Albrecht, Mary F. Fauci, Katherine W. Skirvin, and David F. Bezdicek

Introduction

Organic matter is an important soil component. Grassland soils are noted for their high levels of soil organic matter (SOM) and high structural stability. Unfortunately, when grasslands are converted to croplands, most traditional agricultural management systems degrade SOM. The rapid loss of SOM with cultivation is well documented. Soil organic matter impacts water infiltration and water holding capacity, nutrient-holding capacity, structure, and buffering capacity, making SOM of prime importance in any agroecosystem (de Jong, 1981; Elliott, 1986; Janzen, 1987; Low, 1972; Monreal et al., 1995). The loss of SOM increases the possibility of erosion by wind and water, decreases overall soil quality, and ultimately reduces agricultural sustainability.

Soil organic matter can be considered as an array, or succession, of components that are difficult to distinguish from one another. However, the movement of organic material into and out of SOM fractions can be estimated using either chemical or physical methods (Christensen, 1992). In some cases, the fractions have been characterized by decomposition rate (Jenkinson and Raynor, 1977).

To describe SOM dynamics adequately, it is important to isolate and characterize biologically active fractions from soil (Cambardella and Elliott, 1994; Christensen, 1995). The

active fractions consist of living and dead organic materials that are subject to rapid biological transformations. It has been shown that the acid hydrolysis of soil provides a reasonable estimate of active and stable SOM fractions (Xu et al., 1997).

Organic matter can be isolated by purely physical means. Particulate organic matter (POM), that fraction of the organic matter larger than 0.002 inch, can be obtained using a standardized sieving technique. Cambardella and Elliott (1992) suggest that POM fractions can match selected SOM fractions (e.g., decomposable SOM, stabilized SOM) that have been utilized in SOM simulation models.

The extensive use of tillage for weed control and seedbed preparation has caused a loss of SOM and a deterioration in soil quality in the semiarid Columbia Basin. Concern about this loss has stimulated interest in no-till agriculture. As sustainable soil management practices are being implemented across the Pacific Northwest (Veseth, 1999), the ability to estimate SOM fractions quantitatively in both conventional and no-till soil management practices is especially important for understanding SOM dynamics. Our objectives were to determine the distribution of SOM fractions within the soil and to assess the impact of long-term management systems on these fractions. Soil from long-term conventional and no-till sites was evaluated for total soil carbon (C),

POM, POM-supported microbial respiration, and stable SOM.

Materials and Methods

In spring 1998, soil samples were collected from five of the long-term experiments at the Pendleton Agricultural Research Center 11 miles northeast of Pendleton, OR. These experiments have a documented history of tillage cultivar, soil amendments, and yield. They have been described in detail by Rasmussen and Smiley (1994).

Samples were taken from the following treatments:

Continuous Cereals (CW)—

Established in 1931, cropped annually to winter wheat (*Triticum aestivum* L.), the site was modified in 1982 to include spring wheat and spring barley (*Hordeum vulgare* L.). The experiment is moldboard plowed and receives both chemical and mechanical weed control.

Grass Pasture (GP)—Maintained as permanent pasture since 1931, it was grazed until 1985 but has not been grazed since. It is clipped once or twice a year, and the clippings remain on the field. It is reseeded periodically with introduced grass cultivars and fertilized occasionally.

No-Till (NT)—Started in 1982, it was cropped annually (wheat) from 1982 to 1988, then converted to winter wheat/summer fallow. Wheat stubble is flailed and left on the field. There are five levels of N fertilization.

Residue Management (CR)—

Established in 1931, the rotation is

winter wheat/fallow. The tillage is moldboard plowed, and residue is burned in the spring.

Soil samples were taken from the top eight inches in three increments (0 to 2, 2 to 4, and 4 to 8 inches), oven-dried, crushed, and passed through a 0.08-inch screen. Soil samples were composites (ca. 1 pound total) of six subsamples taken from each treatment replication. There were at least three replications for each treatment. The particulate organic matter (POM) size fraction from the soils was isolated by shaking for 16 hours in a dispersing agent and passing over a 0.002 inch sieve. The POM remaining on the sieve was analyzed for total carbon and nitrogen, correcting for sand in the sample.

To determine POM respiration, distilled water was added to 0.35 ounce, dry POM material to bring it to near saturation before incubation at 72°F. Carbon dioxide (CO₂) flux from the POM was measured by a Hewlett Packard model 5370A gas chromatograph. To determine the stable carbon fraction, soil was treated with boiling acid (six molar hydrochloric acid) for 18 hours (H.C. Collins, personal communication). The residual acid was removed by repeated washing with distilled water and collection of the soil by centrifugation (Sorvall, RC-5B with SS-34 rotor). The acid-treated soil was dried, ground in a mortar and pestle, and analyzed for total carbon and nitrogen. Total carbon and nitrogen were determined on a Fisons model NA 1500 carbon-nitrogen analyzer.

Results and Discussion

Particulate organic matter carbon accumulates at the surface in the pasture and no-till soils. Tillage created an even distribution of POM-C throughout the profile (Figure 1).

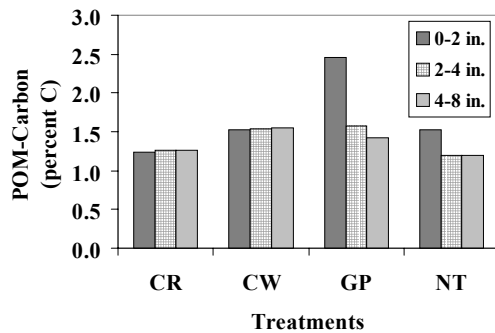


Figure 1. Particulate organic matter at different depths from long-term experiments near Pendleton, OR. CR = Crop Residue; CW = Annual Winter Wheat; GP = Grass Pasture; NT = No-Till

Particulate organic matter-C increased as a percentage of total soil carbon under reduced tillage (data not shown). The amount of POM-C in the soil was linearly related to the soil C content and was related to the type of tillage.

The cumulative amount of POM-C respired at 50 days was highest at the surface of pasture and no-till soils. Under conventional tillage, the POM was evenly distributed throughout the profile and had similar mineralization rates (Figure 2). The 50-day POM-carbon respiration measurements from lower soil depths in reduced tillage treatments is more recalcitrant than surface POM. Under conventional tillage, POM mineralization (i.e., the conversion of

POM to CO₂ by the action of soil

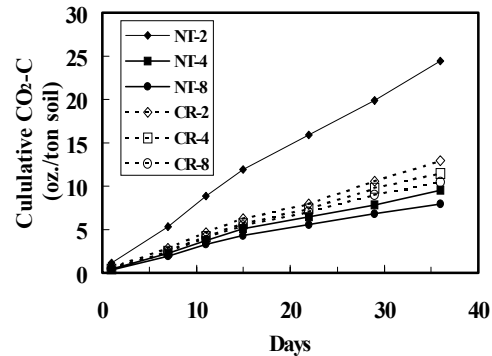


Figure 2. Particulate organic matter respiration, at three depths (0-2, 2-4 and 4-8 inches), from the Crop Residue (CR) and No-Till (NT) long-term experiments near Pendleton, OR.

microorganisms) is similar at all depths within the tillage zone and POM respiration is intermediate between that of the surface and lower depths of no-till systems. Particulate organic matter-carbon respiration reflected the amount of POM-carbon in the soil. Overall, on a POM-carbon basis, POM-carbon was more labile at the surface than from lower depths.

The amount of stable carbon is relatively uniform to a depth of eight inches in a conventionally-tilled wheat/summer fallow (CR) system (Figure 3). However, in an undisturbed location (GP), at the upper soil depth, the stable carbon content is greater than in a tilled system. The amount of stable carbon, in relation to total carbon, was less in the grass pasture system (Figure 4), indicating that an active fraction increases, especially at the upper soil depths, as tillage intensity decreases. Reducing tillage and eliminating fallow increased carbon sequestration in soils as measured by soil C.

Summary

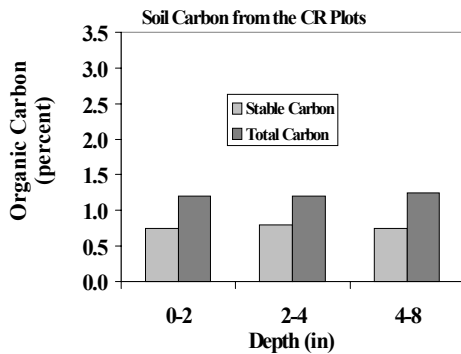


Figure 3. Comparison of total and the stable carbon fraction from the Crop Residue (CR) experiment near Pendleton, OR.

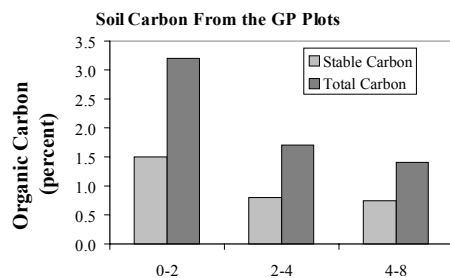


Figure 4. Comparison of total and the stable carbon fraction from the Grass pasture (GP) pasture experiment near Pendleton, OR.

In the Pacific Northwest, yearly crop production is recommended because cropping systems that include summer/fallow lose SOM over time. Decreasing tillage intensity can reduce SOM loss; however, the outcome usually is not as effective as eliminating summer/fallow. Carbon loss from summer fallowed soils is great because fallowing keeps the soil moisture content relatively high during the summer when temperatures are raised, allowing elevated rates of SOM mineralization by soil microorganisms.

Under conventional tillage, POM-carbon was distributed evenly throughout the soil profile and had similar mineralization rates. Particulate organic matter-carbon accumulated at the surface of pasture and no-till systems. The POM-carbon that accumulated at the surface of no-till and pasture systems was more labile than the POM-carbon from lower depths. This suggests that the POM-carbon at the soil surface had not mineralized, or decayed, to the extent of material inverted and mixed by plowing.

Stable carbon (i.e., resistant to acid treatment) was distributed uniformly in the top eight inches of soil subjected to conventional tillage. However, it accumulated in the upper levels of soils that were not tilled. This stable carbon fraction represents the carbon material that provides many beneficial soil characteristics. The aggregation of this material in a no-till system suggests that reduced tillage impacts soil quality positively.

Acknowledgements

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